MSFC Tech Days

The COI Semi-Rigid Hybrid Mirror

Kelly J. Dodson

Agenda

- Hybrid Design Overview
- Optical Processing
- Modal Correlation
- Cryo Test 1
- Optical Processing
- Cryo Test 2
- Optical Processing
- Cryo Test 3

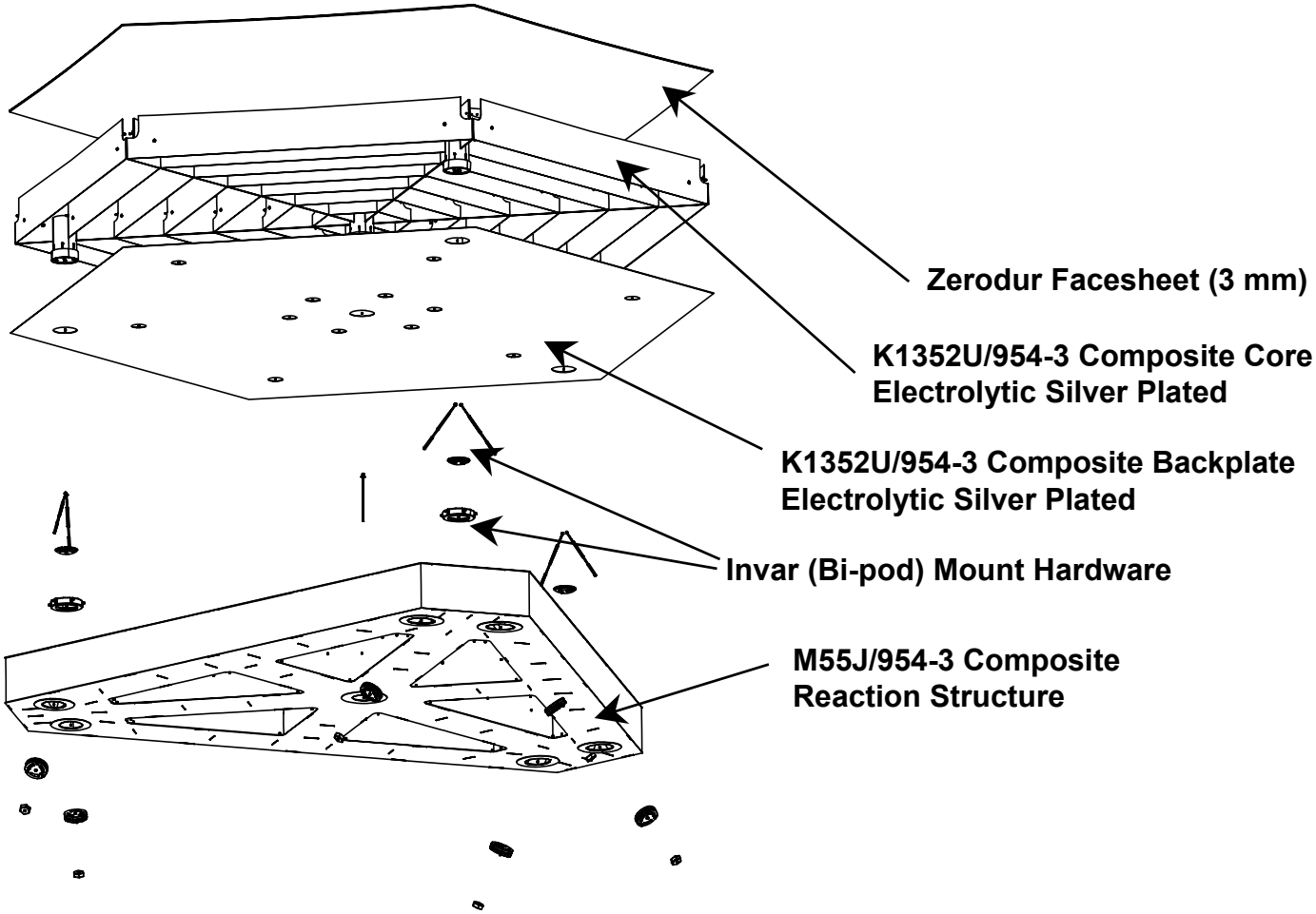
NMSD Program Requirements

Parameter	Value	Goal
Shape	Spherical	
Aperture	1.6m	
F/No.	f/6	f/5
No. of Actuators	A/R for figure and/or phasing	
Figure	$<\lambda/4$ PTV (visible)	$<\lambda/10$ PTV
Mid-Spatial Errors	$<\lambda/10$ PTV (visible)	$<\lambda/20$ PTV
Mid-Spatial Scale	1 - 10 cm	
Finish	<2 nm RMS	1 nm RMS
Areal Density (PMA)	$15kg/m^2$	$<15kg/m^2$

NMSD Hybrid Design Overview

- **Combine Desirable Attributes of Both Glass and Composite**
- **Structurally Efficient (Bonded) Sandwich Construction**
  - **Zerodur Facesheet**
  - **Composite Backplate and Core**
    - **Low Mass, High Stiffness Support for Zerodur Facesheet**
    - **Thermal Expansion Match of Zerodur (Ambient to 35K)**

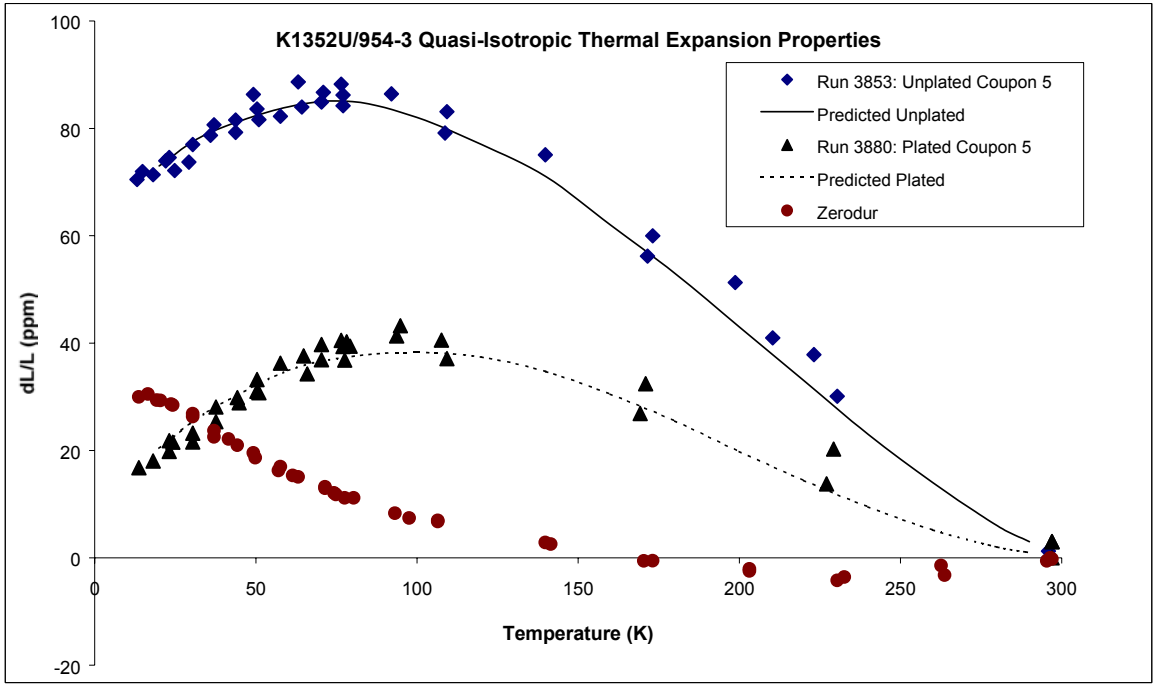
Hybrid Design



- **Primary Mirror Assembly Areal Density: 15kg/m^2**
  - **Mirror Substrate: 11kg/m^2**
  - **Reaction Structure and Invar Mounts: 4kg/m^2**

Processing of NMSD Components

- **Approach to Thermal Expansion Matching of Composite to Zerodur**
  - **Lamination and Cure Control to Target dL/L Behavior**
  - **Plating of Composite Elements to Fine Tune dL/L to Match Glass**



Test Objectives

- **Objectives for Cryo Test 1 and 2**
  - **Demonstrate the Modal Characteristics of the PMA, Substrate, and Reaction Structure**
  - **Provide Basic Optical Performance of the Substrate at 35K in Simulated Zero-g Condition**
  - **Observe the Basic Behavior of The Hybrid Construction**
  - **Data Feeds Back into the Analytical Understanding of the System**
- **Objective for Cryo Test 3**
  - **Final Optical Demonstration after mid spatial correction**

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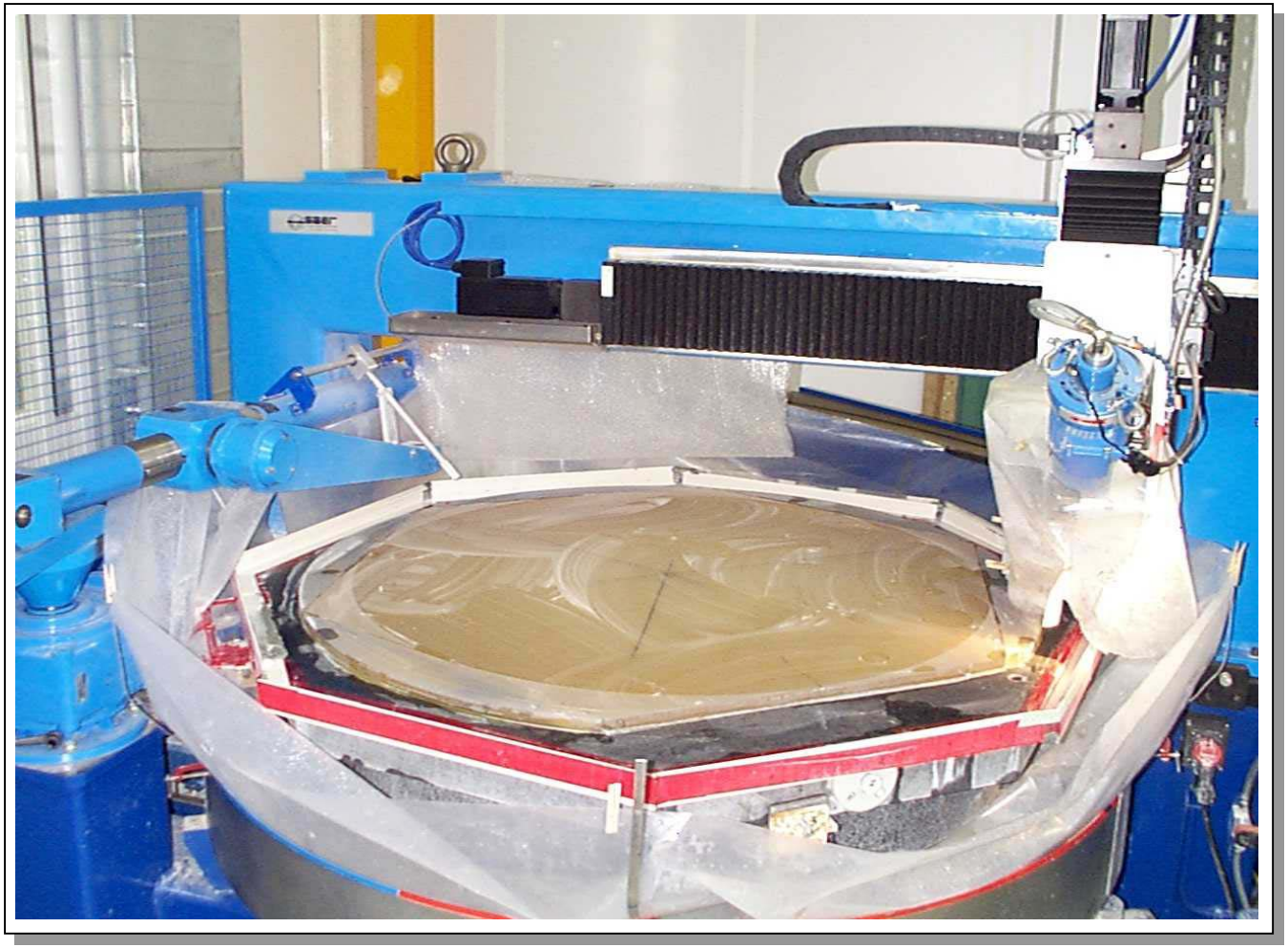
Optical Fabrication

NMSD Mensicus on Granite

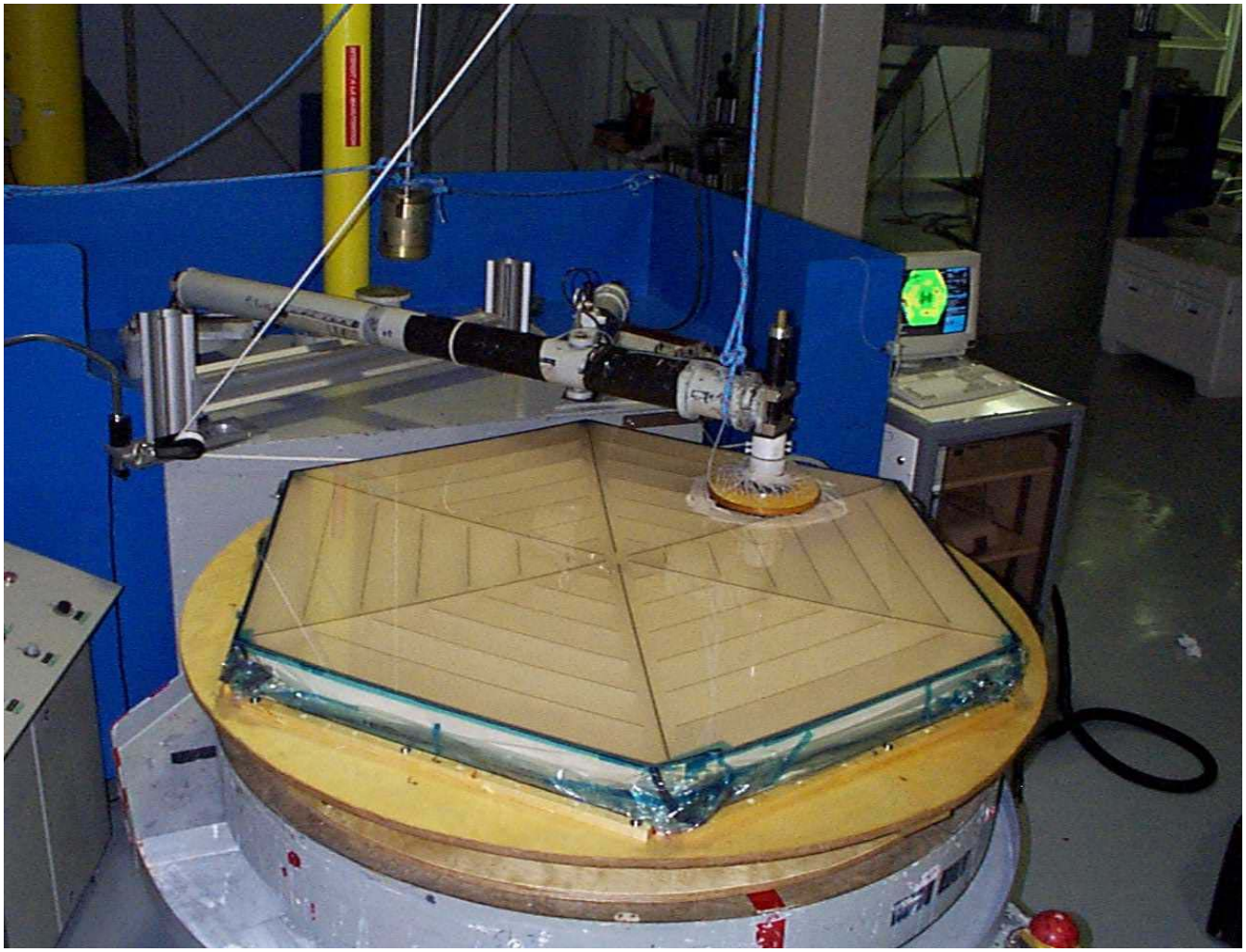
NMSD Meniscus Grinding



NMSD Polishing Strategy

- The Polishing Strategy must be able to:
  - correct for the meniscus distortion induced by the bonding.
  - limit the quilting effect of extremely lightweighted structure.
- The polishing strategy was demonstrated on 300 mm flat subscale risk reduction mirrors
- The selected polishing processes:
  - Low pressure polishing technique
  - Ion - Figuring

NMSD Mirror Polishing



In-Process Testing Strategy

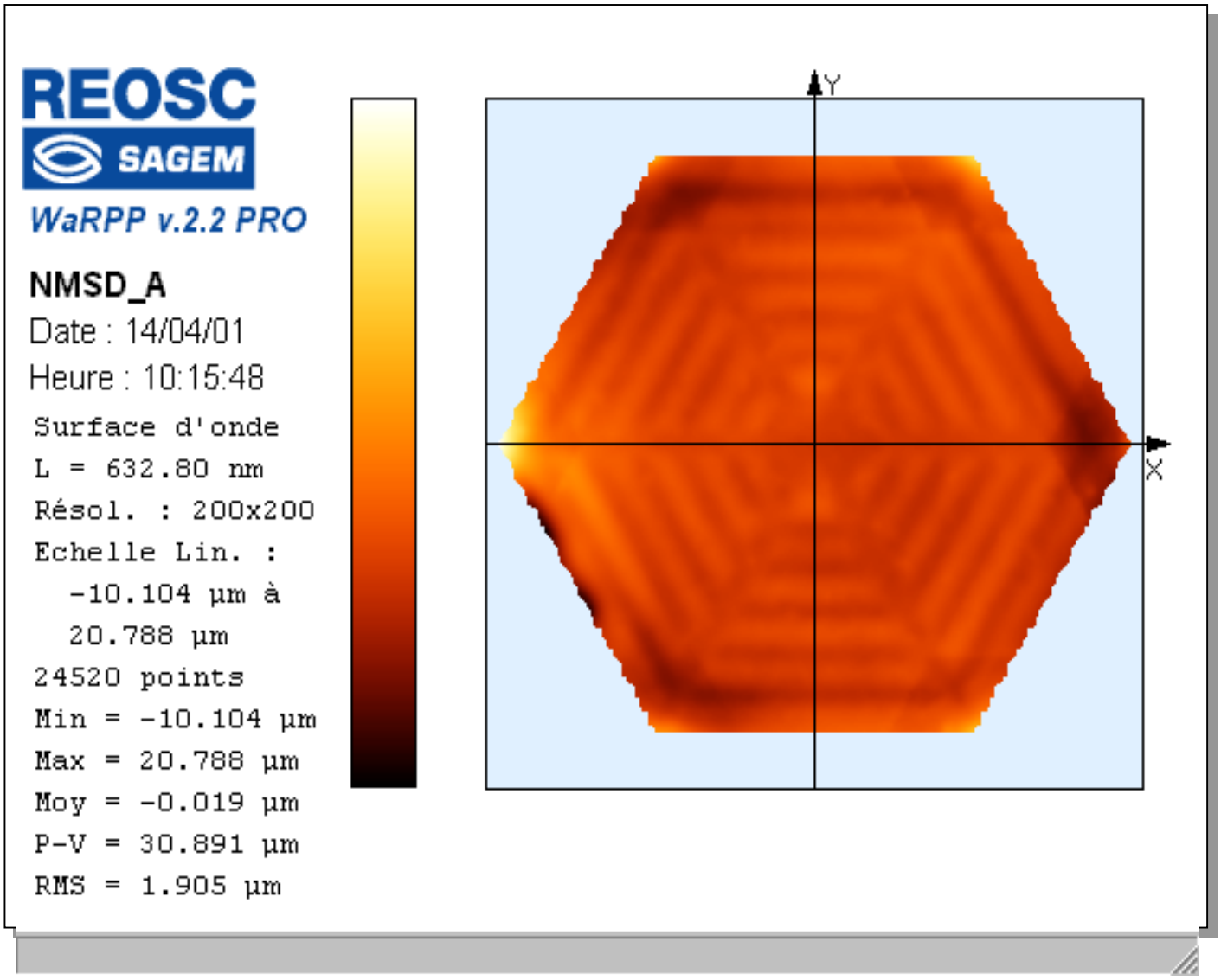
- **CMM Measurements:**
  - **High dynamic range, moderate accuracy, used in early stage of polishing.**
- **IR Interferometry:**
  - **High dynamic range, medium range accuracy, used on poor polished surfaces.**
- **Visible Interferometry:**
  - **SPSI selected for large dynamic range**

CMM Measurements

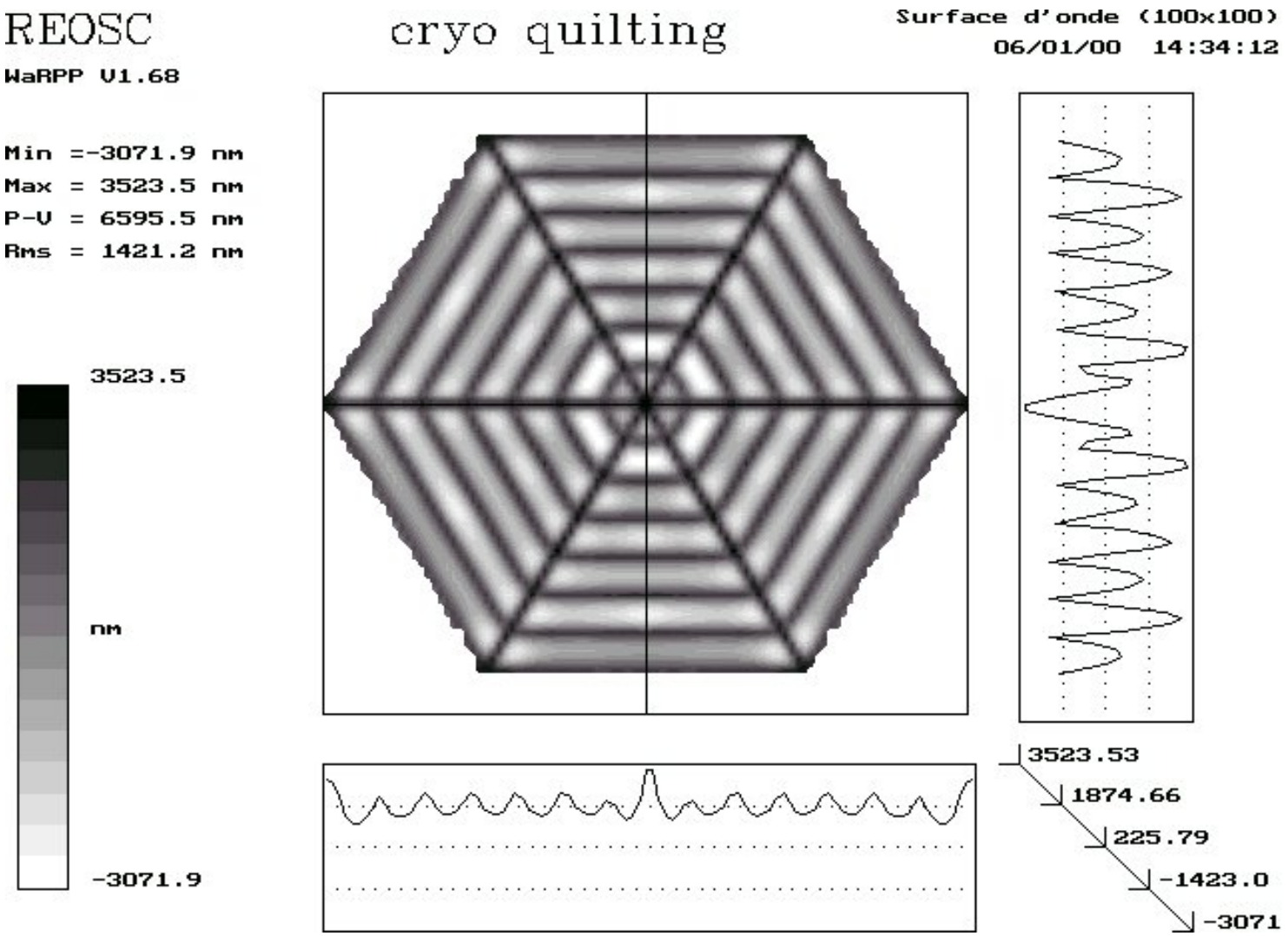
- **Spatial resolution:**
  - 100 x 100 points
- **Vertical Resolution:**
  - 5 µm over 2 x 2 meters
- **Estimated Accuracy:**
  - 5 µm RMS.
- **Measurement Duration:**
  - 2 hours

NMSD Composite Pathfinder on Test Stand

IR Interferometry



NMSD Predicted Quilting for Initial Optical Processing



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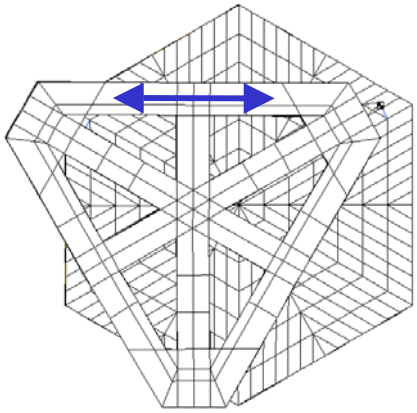
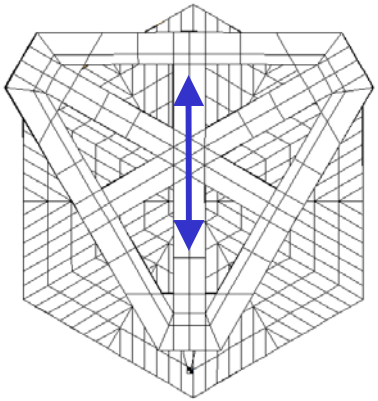
Modal Behavior

PMA Rigid Body (Bi-Pod) Modes

Predicted



118hz



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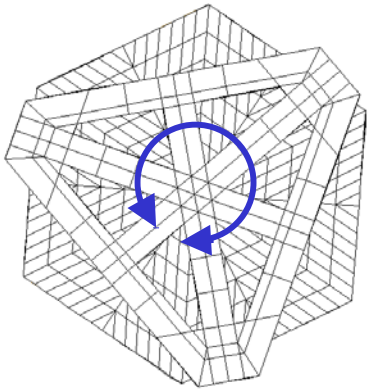
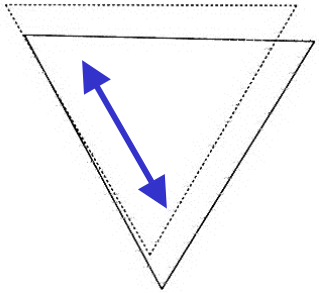


202hz

Measured



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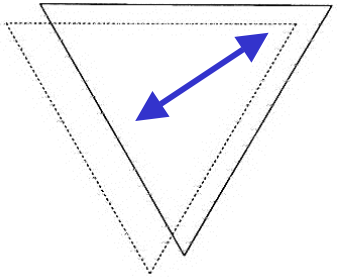

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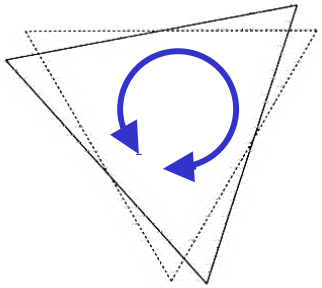
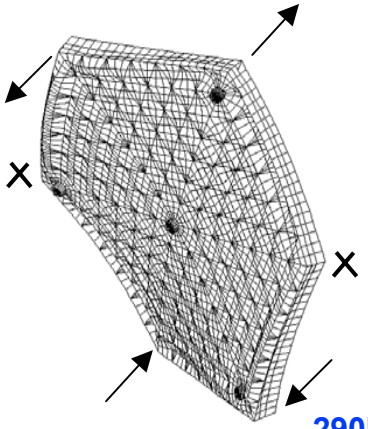
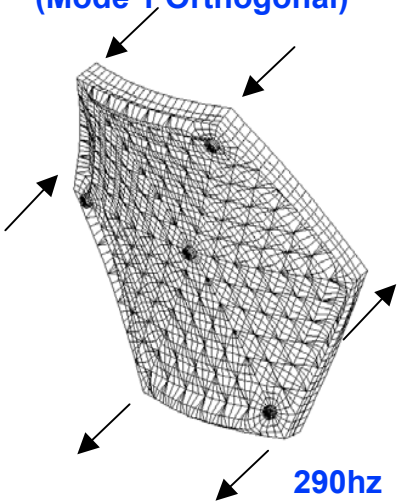
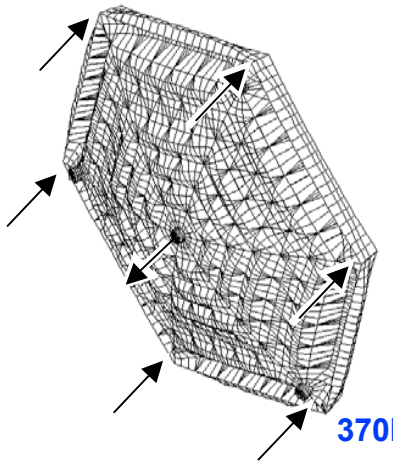
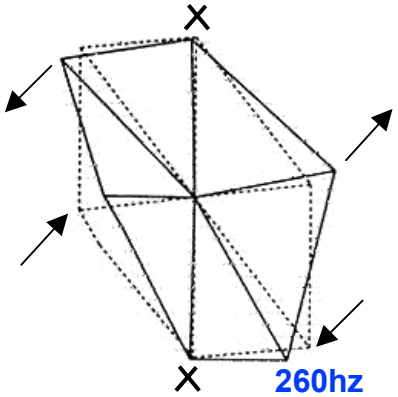
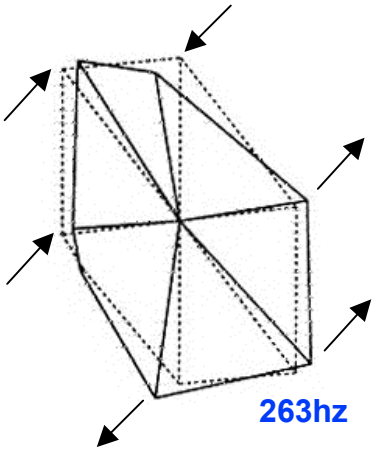
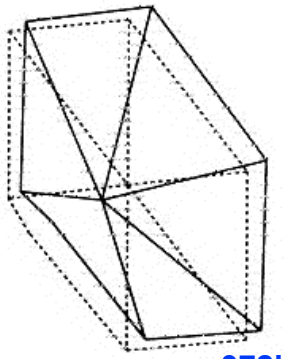


207hz

- Agreement Between the Predicted and Measured Rigid Body Behavior

Flexure Modes of Substrate

	Mode 1: Twist	Mode 2- Astigmatic (Mode 1 Orthogonal)	Mode 3- Axisymmetric
Predicted	 290hz	 290hz	 370hz
Measured	 260hz	 263hz	 372hz

- **Agreement Between Predicted and Measured Bending Behavior of the Substrate**
  - **Modal Values and Mode Shapes**

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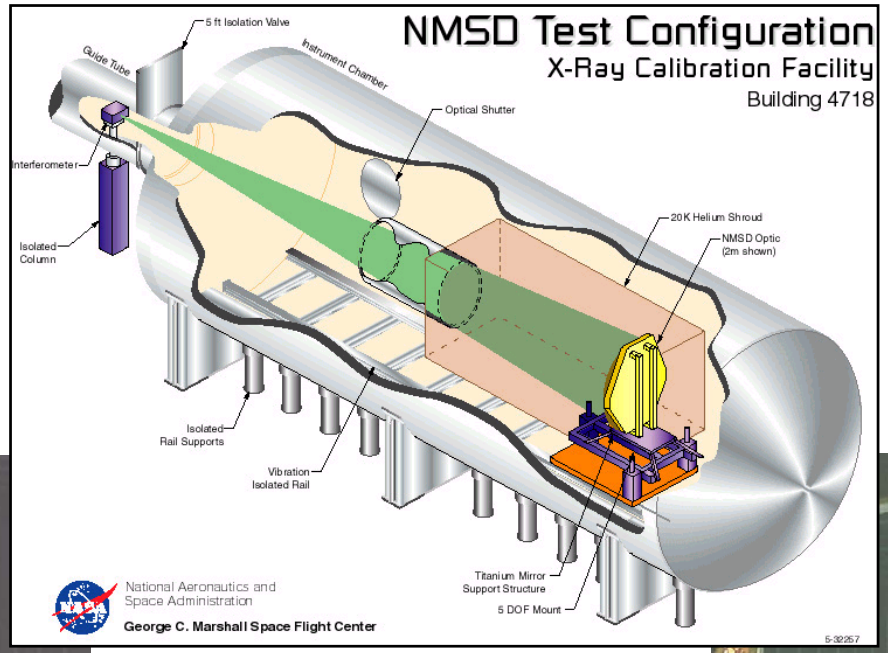
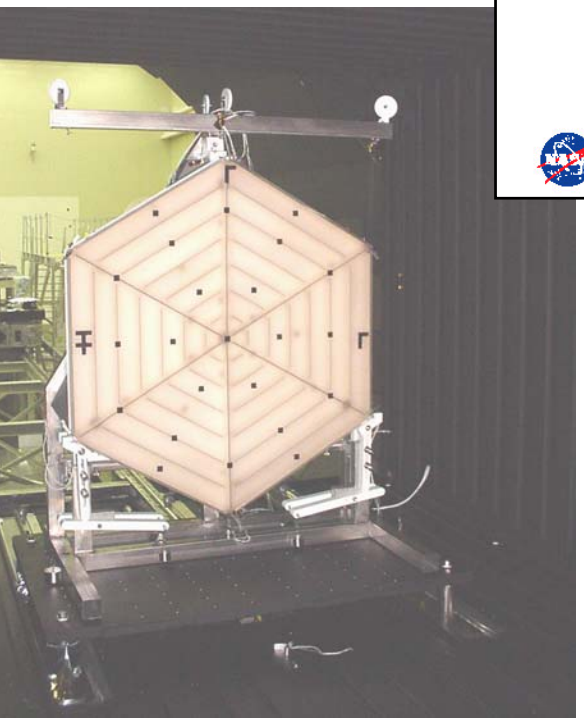
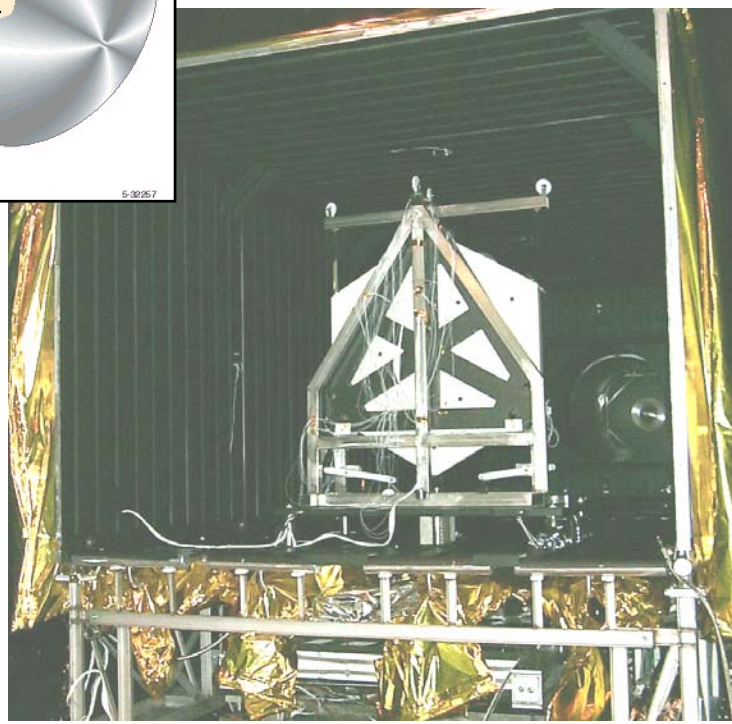
Cryogenic Test Overview

PMA Installation at the XRCF

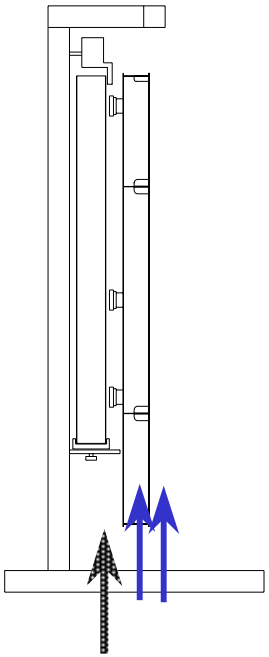


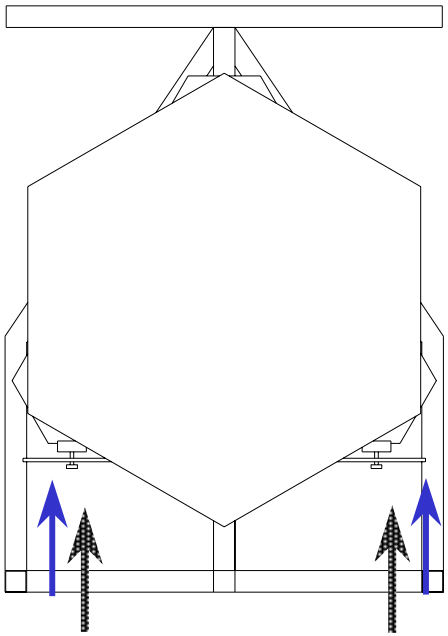




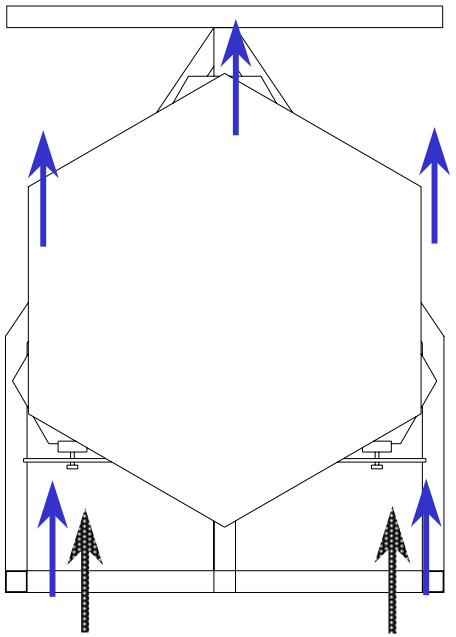
NMSD Gravity Offloading

- **Objective**
  - Minimize Effects to Mirror Figure from Gravity Induced Deflections
- **Approach: Multi-Point Offloading of Mirror Weight**
  - Independent Offload of Substrate



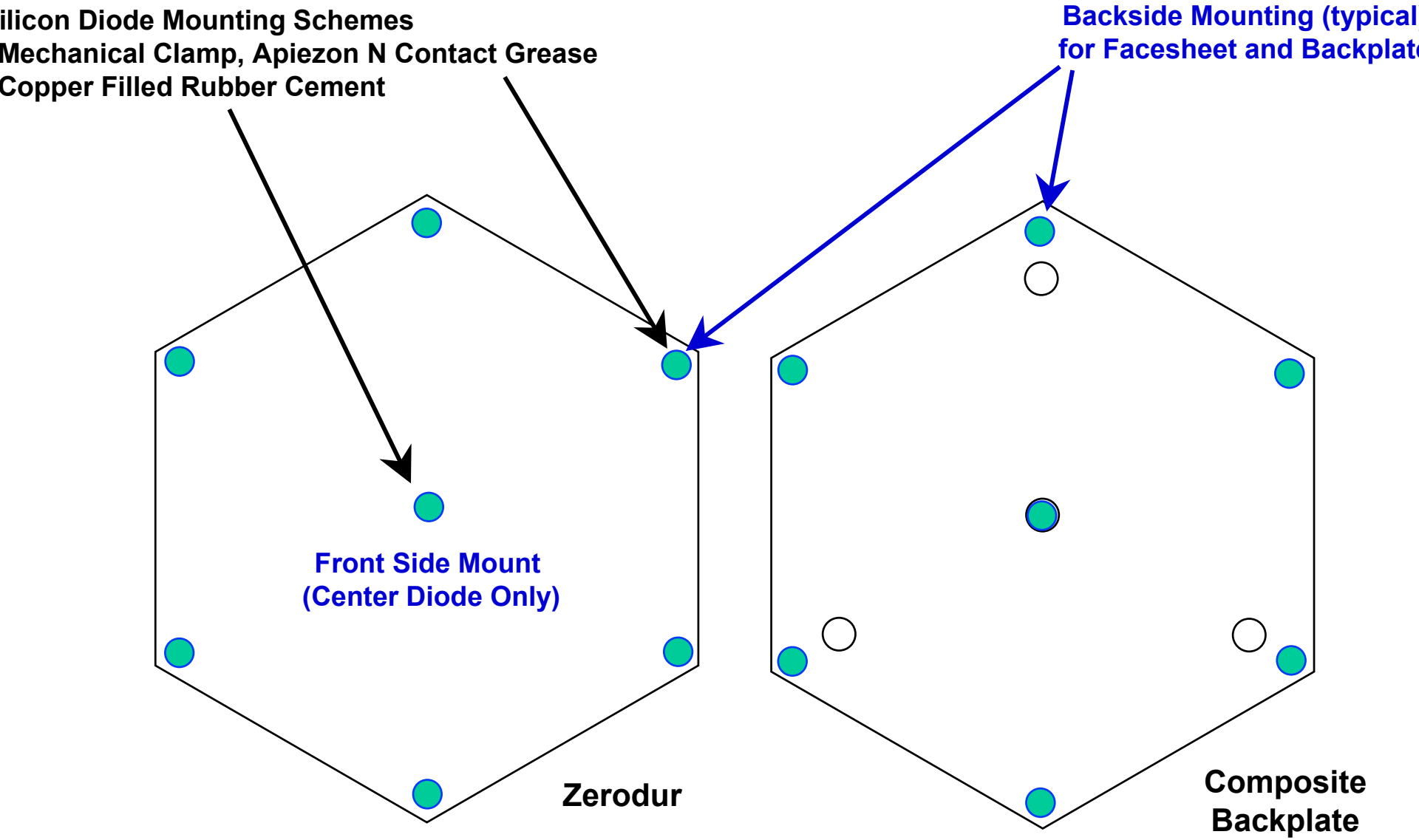


Cryo Test 1 Configuration
Lower Offloading Only

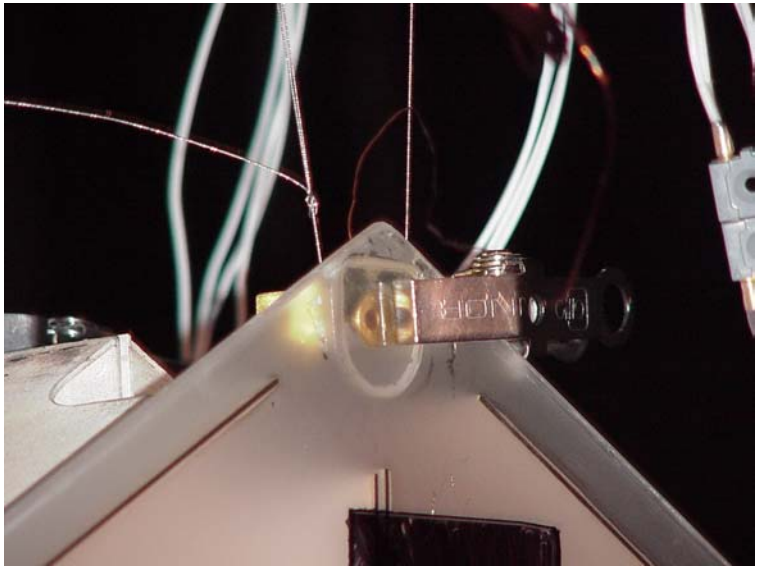


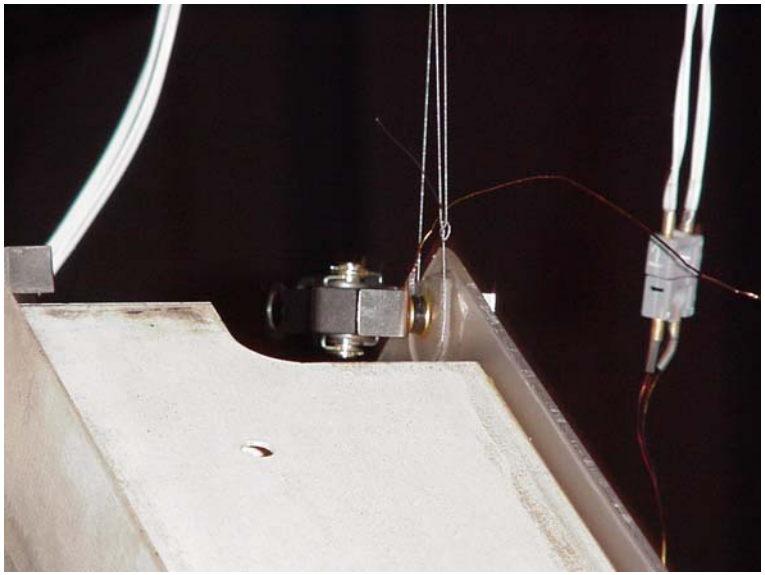
Cryo Test 2 Configuration
Upper and Lower Offloading

Substrate Temperature Monitoring



Silicon Diode Mounting





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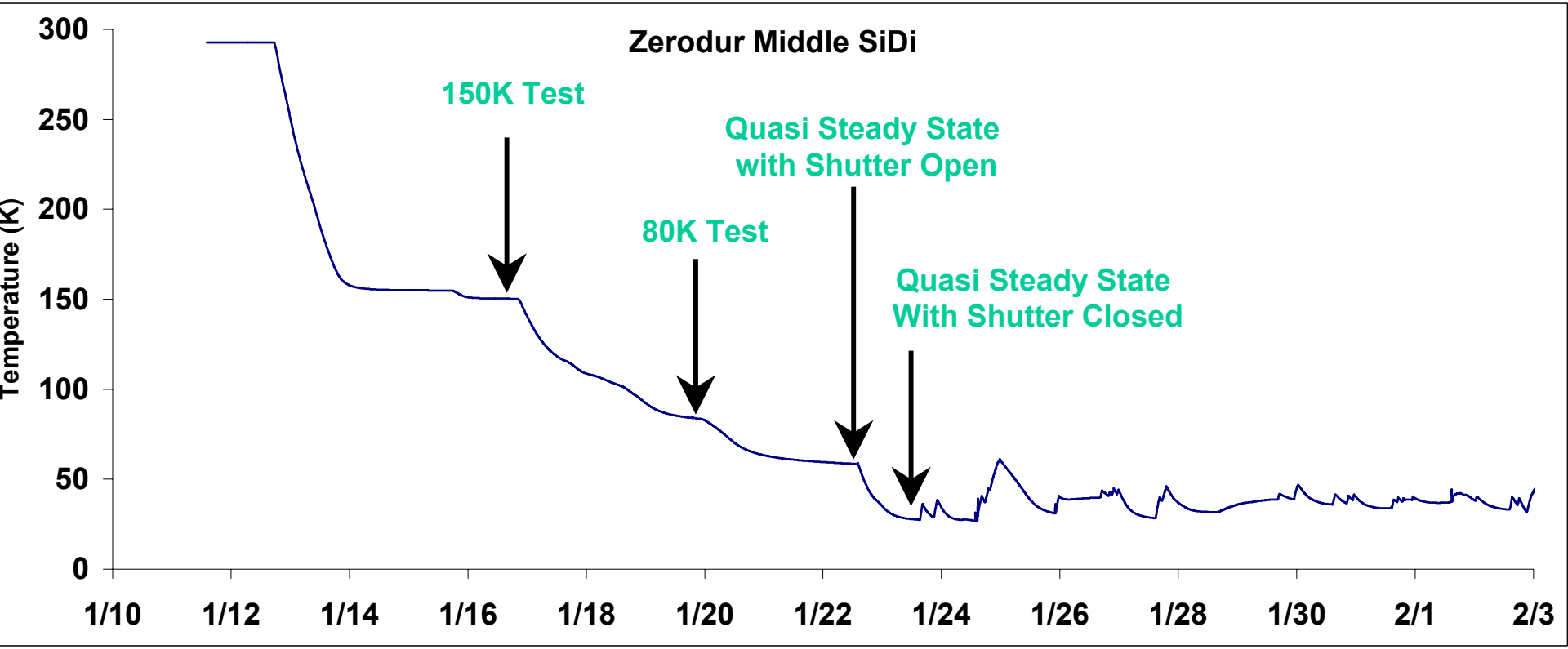
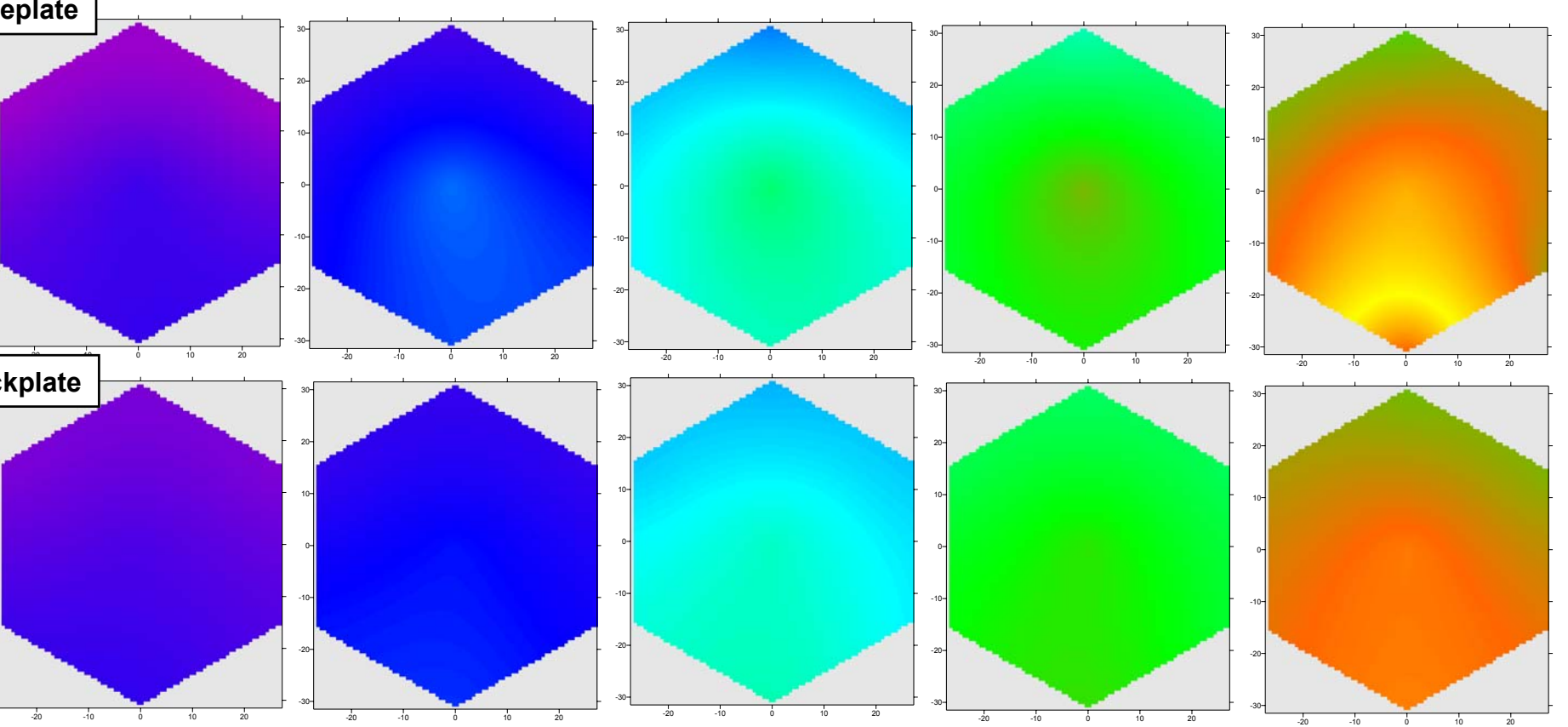
Temperature Measurements

Typical Test Temperatures



Transient Warm-up

Shutter Opened when Cold



Time = 0 | Time = 15 min | Time = 30 min | Time = 45 min | Time = 60 min

	Peak Inplane Gradient (K)		Front/Back Gradient (K)		
Time (min)	Faceplate	Backplate	Mid Aperture	Average	Max
0	1.68	1.20	0.20	-0.24	1.10
15	2.05	1.20	0.85	0.15	1.75
30	2.50	1.40	0.80	0.01	2.00
45	2.80	1.40	0.70	-0.11	2.00
60	2.86	1.48	0.73	-0.10	2.21

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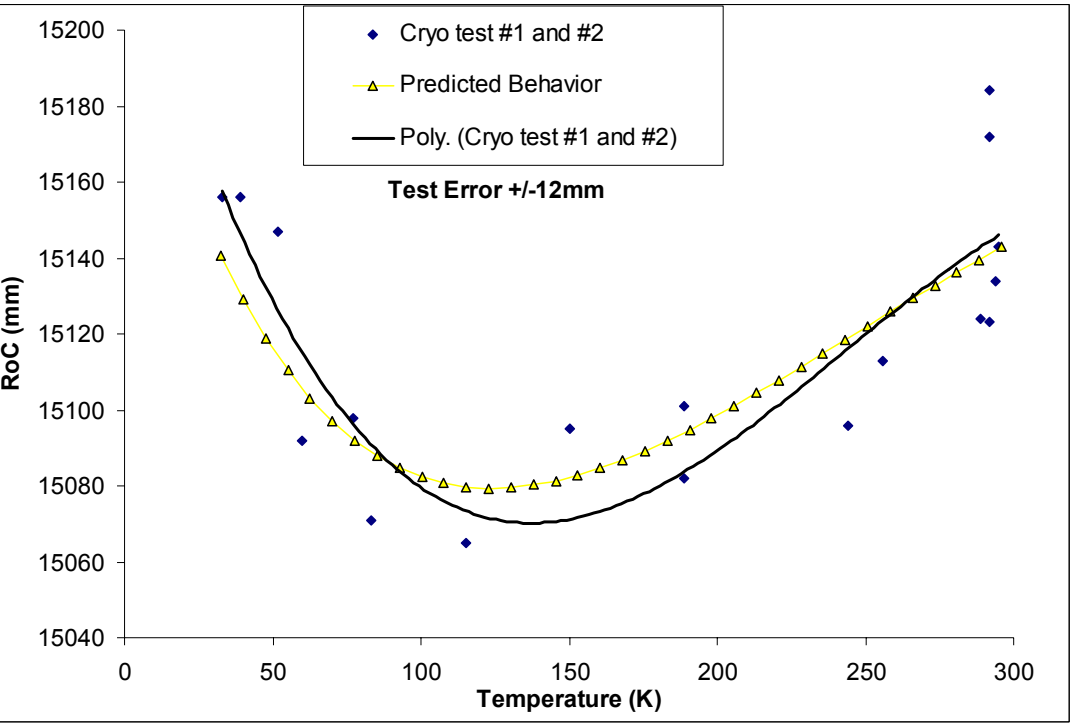
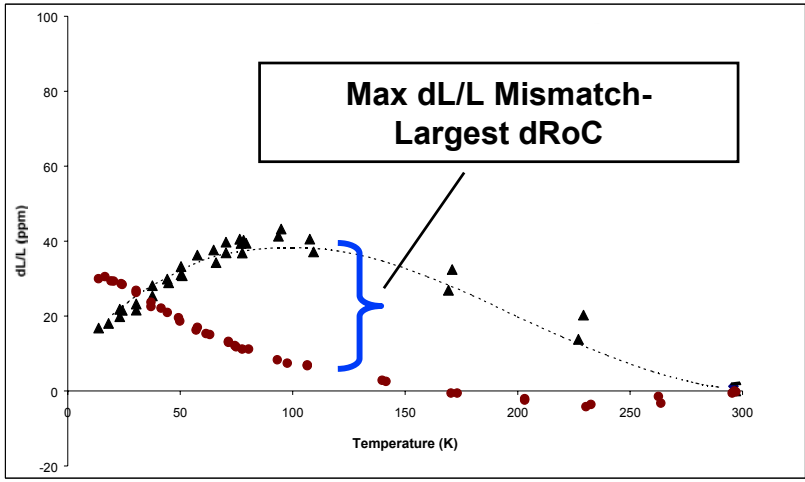
Optical Measurements

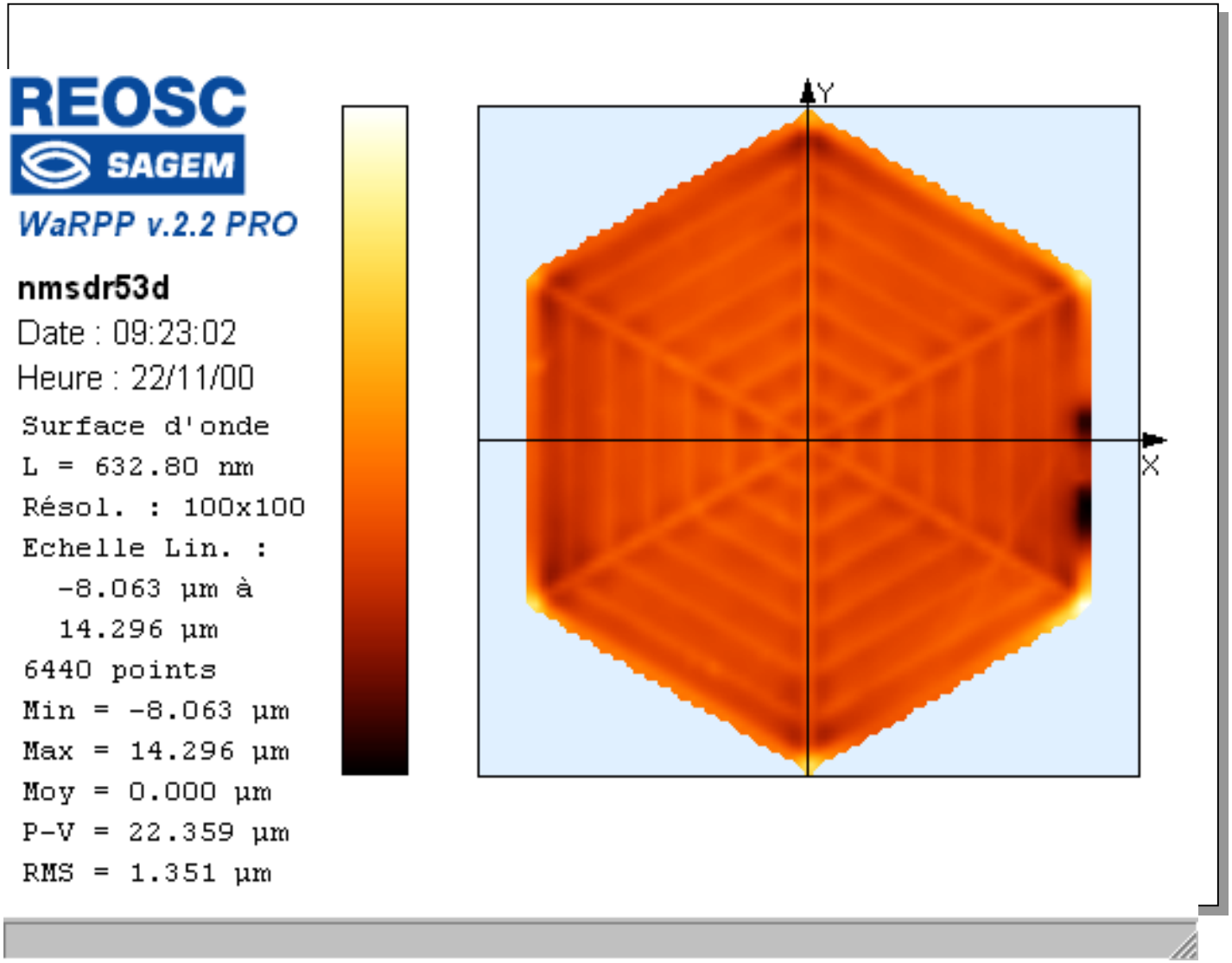
Change in Radius of Curvature



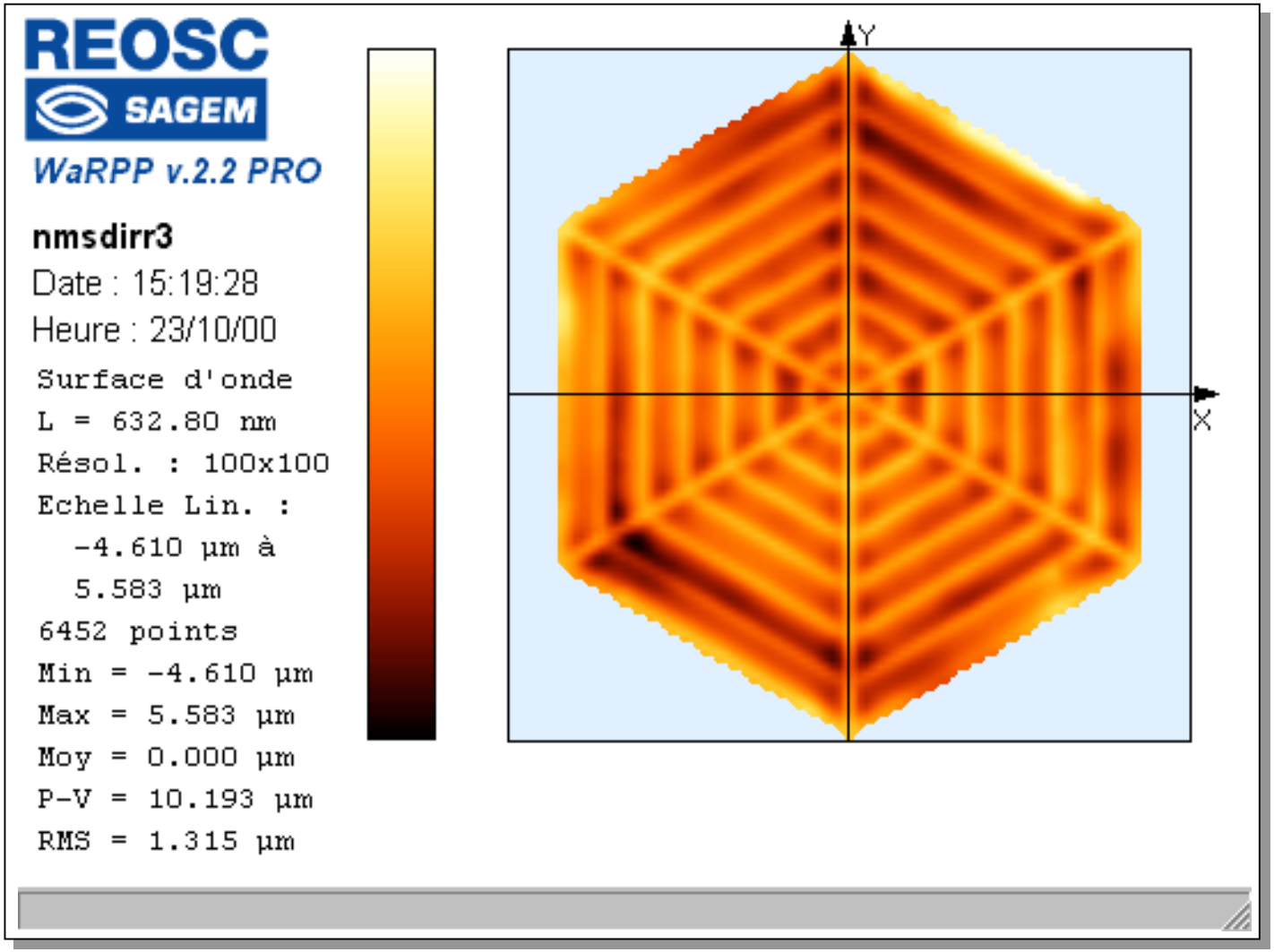


- **Bimetallic Behavior (dRoC) of the Substrate Was Derived from the Coupon Level Thermal Strain Measurements of the Composite and Zerodur**
- **Predicted Change in Radius of Curvature is Consistent With Cryo Test 1 and 2 Measurements**

Second Cryo Correction: CMM Results



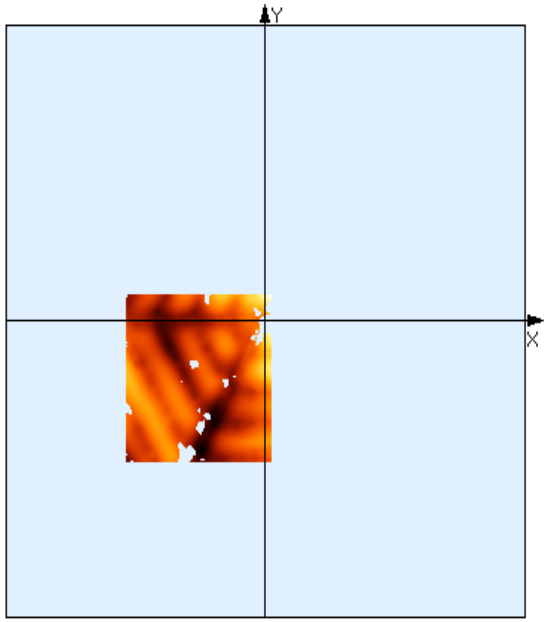
Second Cryo Correction: IR Interferometry



Sub Apertures

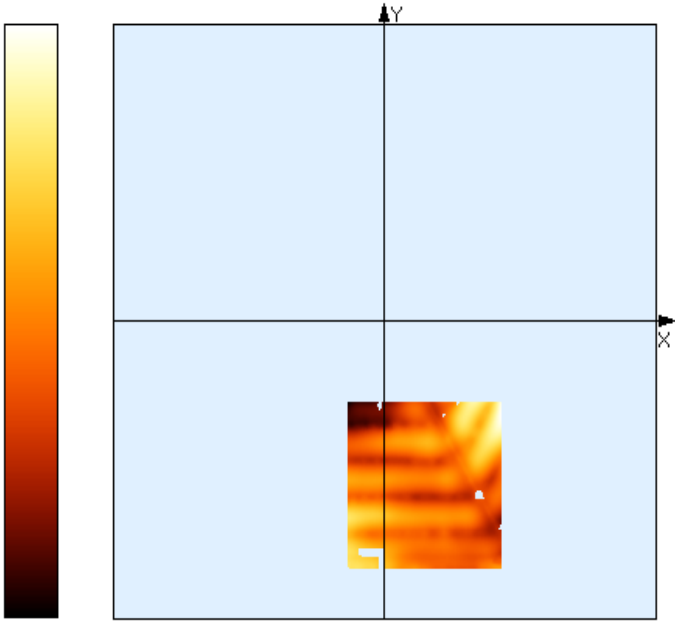
REOSC
SAGEM
WaRPP v.2.2 PRO

1sub59KT
Date : 29/04/01
Heure : 16:25:26
Surface d'onde
L = 632.80 nm
Résol. : 350x350
Echelle Lin. :
-12.081 µm à
-1.468 µm
9504 points
Min = -12.081 µm
Max = -1.468 µm
Moy = -8.343 µm
P-V = 10.614 µm
RMS = 1.614 µm



REOSC
SAGEM
WaRPP v.2.2 PRO

6sub80KT
Date : 08/02/01
Heure : 18:04:21
Surface d'onde
L = 632.80 nm
Résol. : 350x350
Echelle Lin. :
-4.505 µm à
5.160 µm
9751 points
Min = -4.505 µm
Max = 5.160 µm
Moy = 0.050 µm
P-V = 9.664 µm
RMS = 1.543 µm



39K Measurement

REOSC
SAGEM

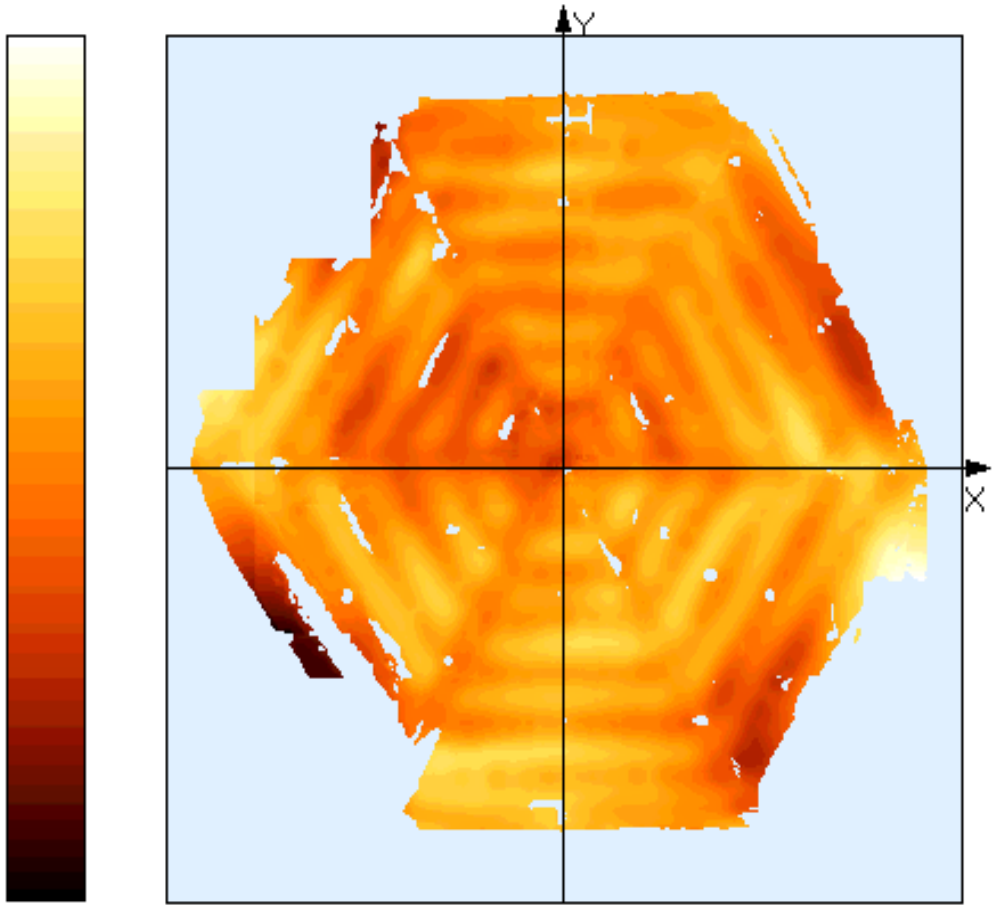
WaRPP v.2.2 PRO

Sous-pupille

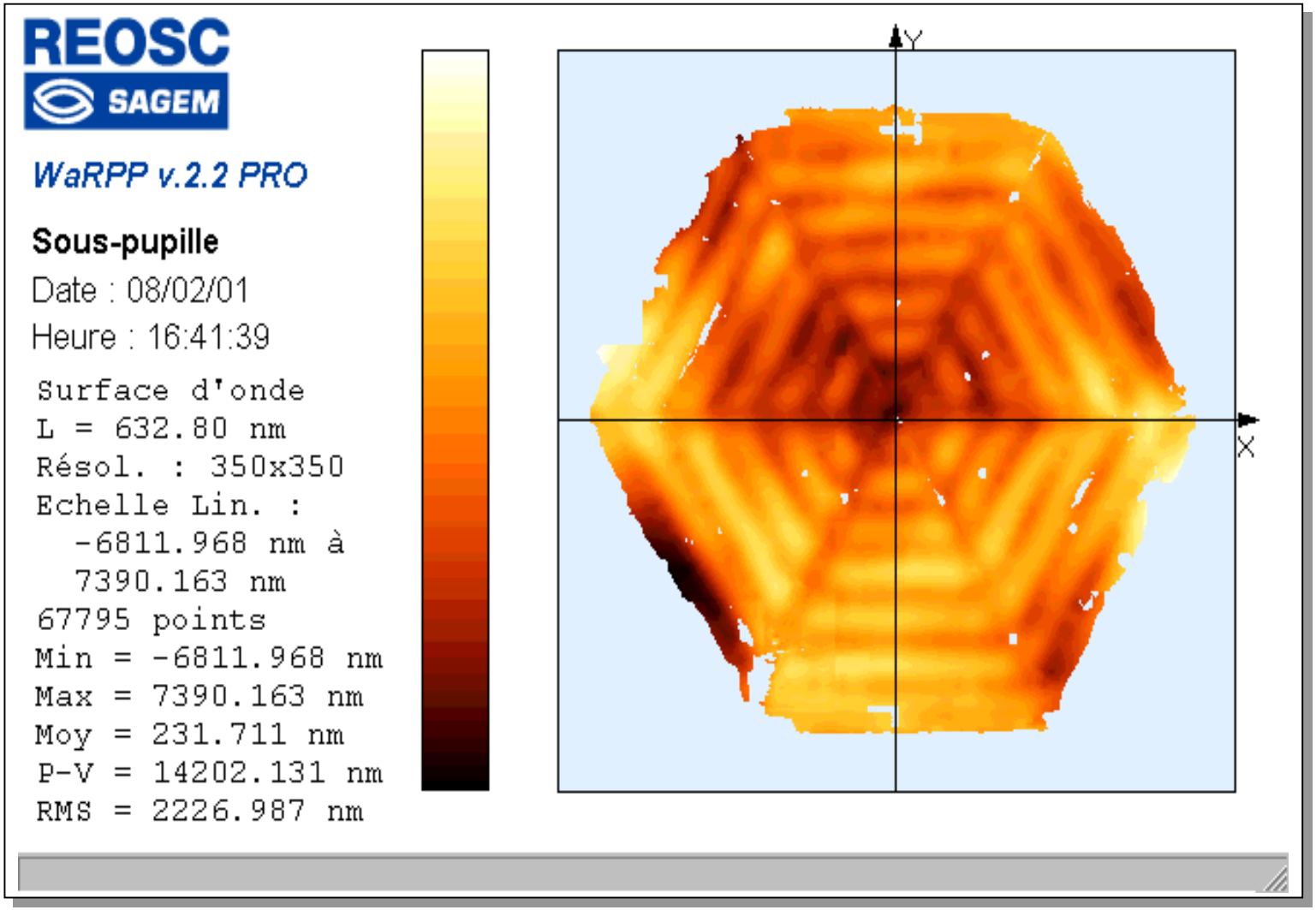
Date : 06/02/01

Heure : 15:57:53

```
Surface d'onde
L = 632.80 nm
Résol. : 350x350
Echelle Lin. :
  -9564.332 nm à
  7980.905 nm
67848 points
Min = -9564.332 nm
Max = 7980.905 nm
Moy = 54.983 nm
P-V = 17545.237 nm
RMS = 1972.754 nm
```

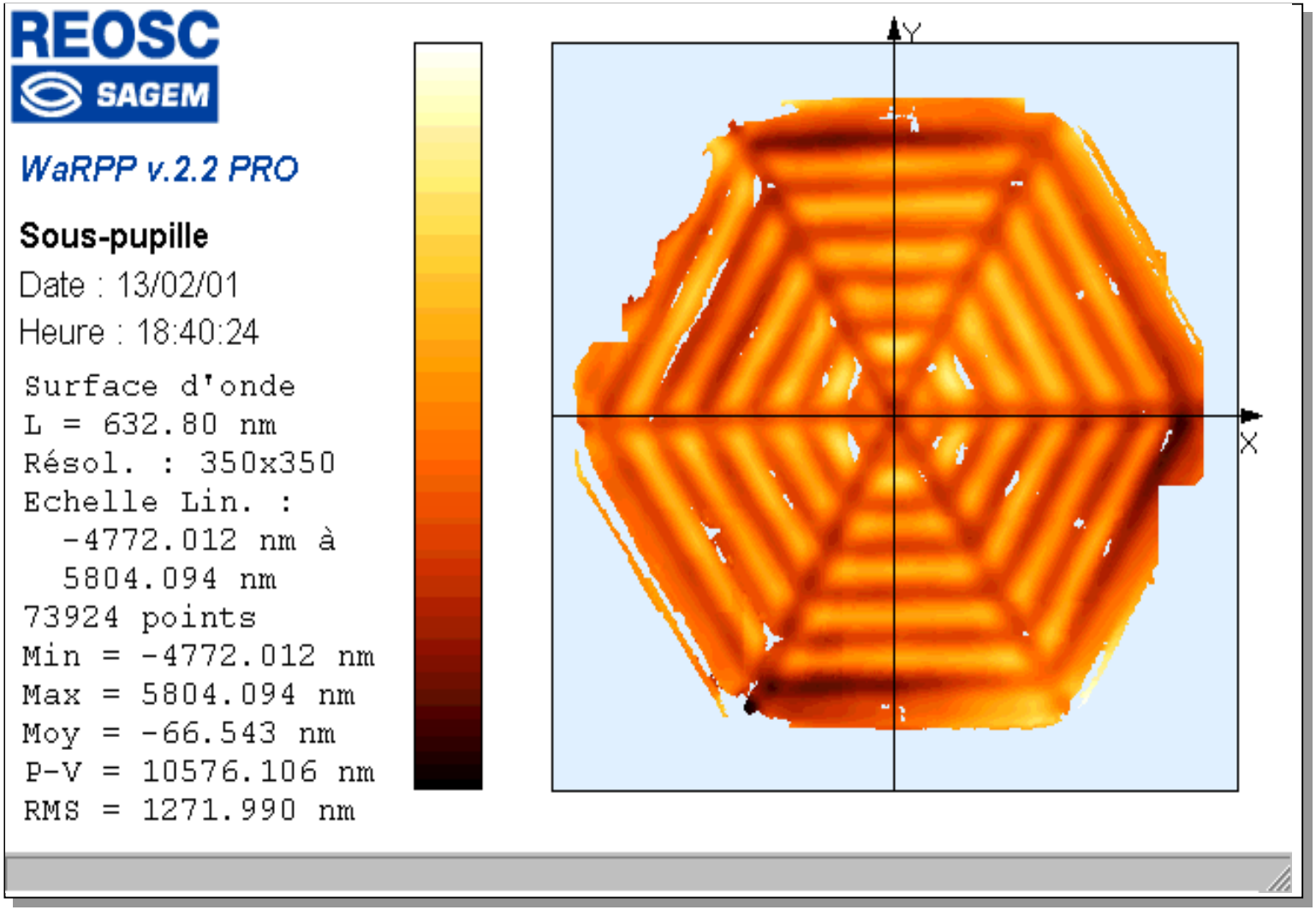


60K Measurement

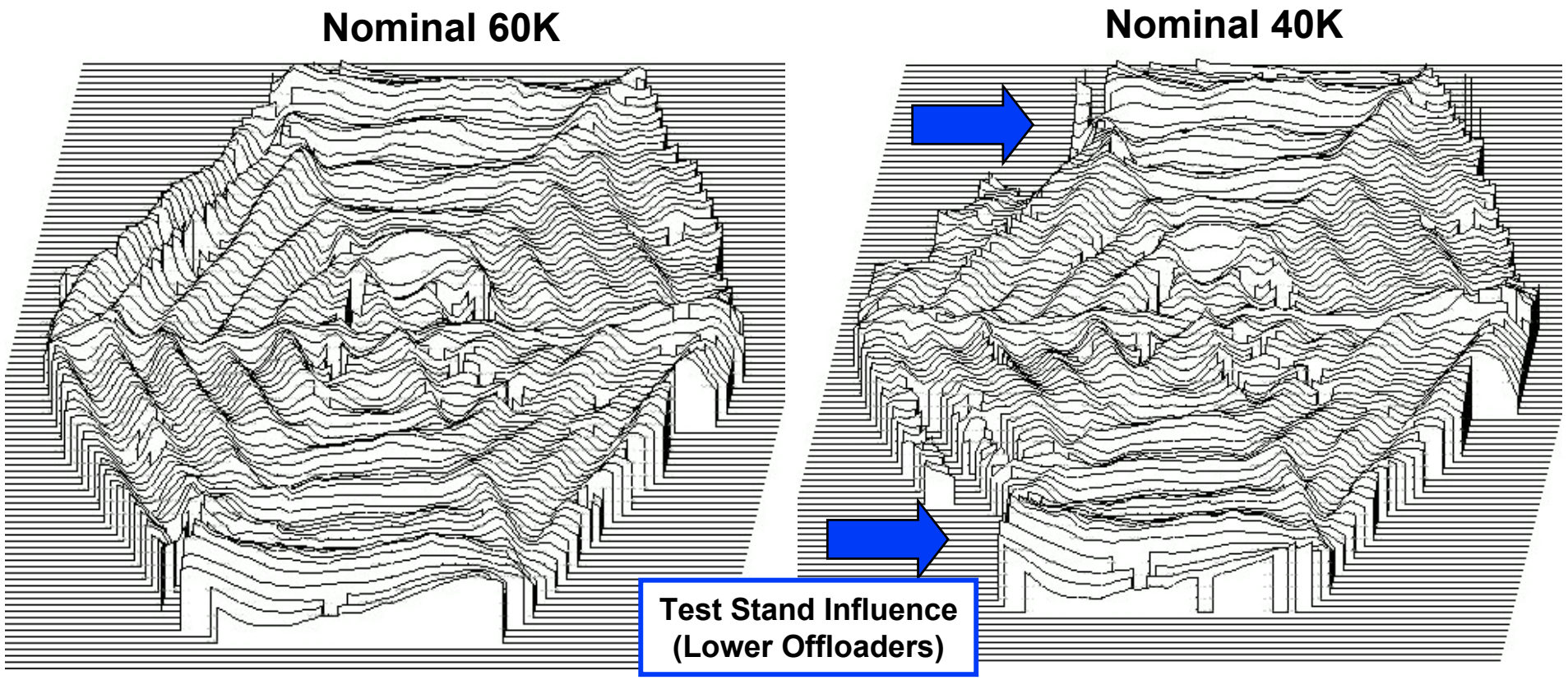


NASA NGST SAGEM Composite Optics, Inc

Ambient Measurement



Quilting- Surface Change from Ambient



- Typical Cryo Induced Quilting for the Substrate: 2.5 to 3.0 micron PTV (Average)
- Quilting Behavior is Consistent Between Test 1 and Test 2
- Cryo Quilting is Basically Constant Across the Temperature Range of 40K to 60K
- Cryo Quilting Corrected by Small Tool Polishing and Ion Figuring
  - The Reverse Condition is Cryo-Figured into the Mirror Surface at Ambient Condition

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Ion Figuring

Measurement at Ambient before ion figuring

REOSC SAGEM

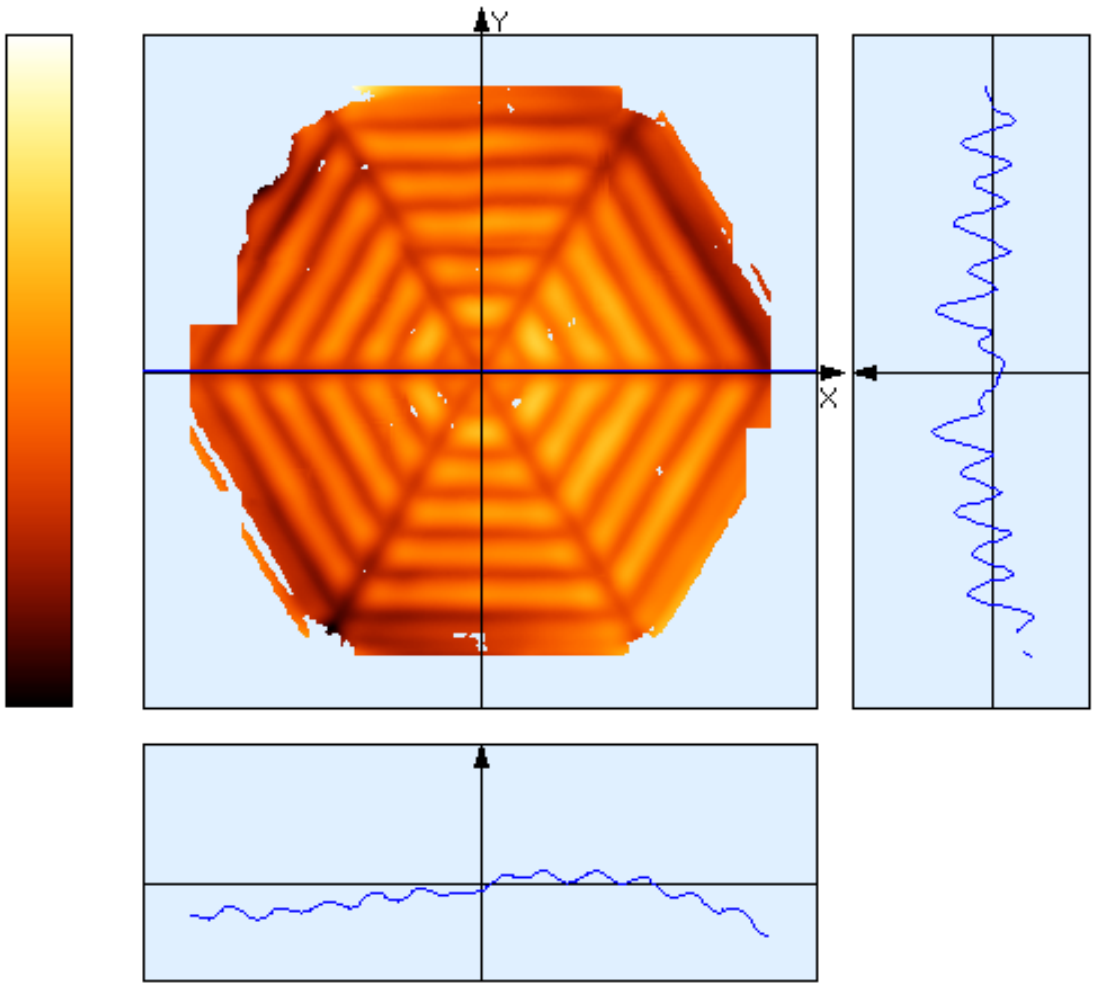
WaRPP v 2.31 PRO

NMSD 293K

Date : 08/10/01

Heure : 15:06:30

Surface d'onde
L = 632.80 nm
R = 0.000 mm
Résol. : 350x350
Echelle Lin. :
-7084.434 nm à
9396.191 nm
73143 points
Min = -7084.434 nm
Max = 9396.191 nm
Moy = -287.566 nm
P-V = 16480.625 nm
RMS = 1727.978 nm



Expected Map at Ambient after ion figuring

REOSC SAGEM

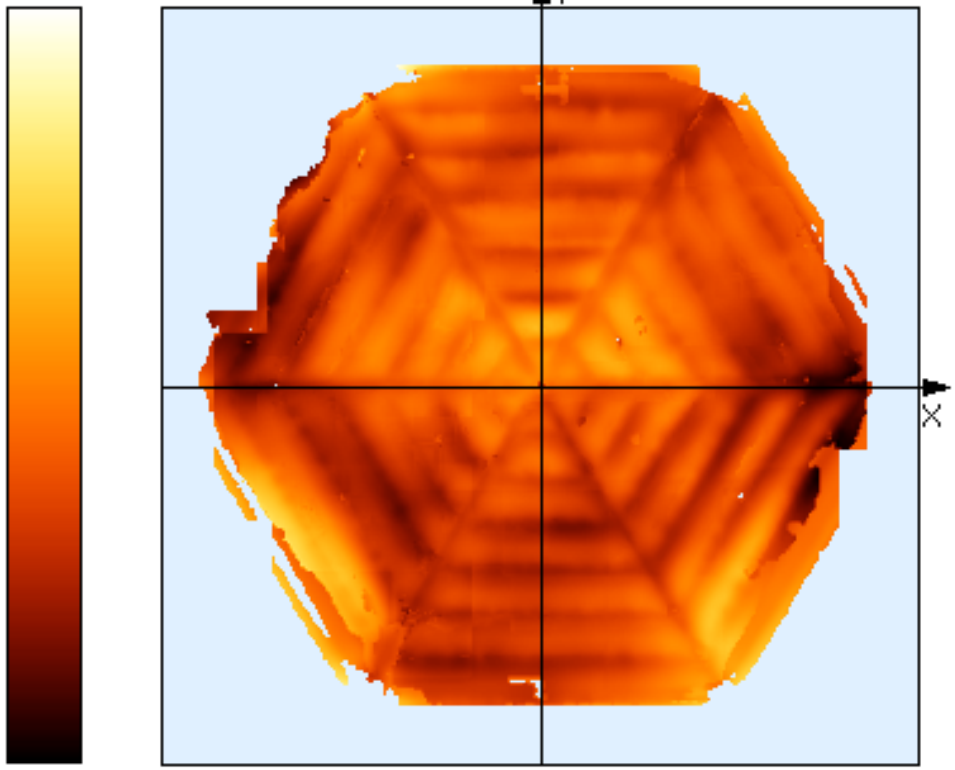
WaRPP v 2.31 PRO

ambient 2

Date : 17/12/01

Heure : 16:23:52

Surface d'onde
L = 632.80 nm
R = 0.000 mm
Résol. : 350x350
Echelle Lin. :
-6992.191 nm à
11720.489 nm
73840 points
Min = -6992.191 nm
Max = 11720.489 nm
Moy = 0.000 nm
P-V = 18712.680 nm
RMS = 2132.864 nm



X = -0.4545 Y = 0.4209 R = 0.6195 Z = -1607.6890 nm

Ion figuring runs

Use of a new ion figuring chamber of 2,5 meters capacity.

Three runs have been performed with intermediate WFE measurements and visual inspection between the run.

Special care has been taken to limit the temperature of the mirror face sheet to 60°C

A total of about 500 hours of ion figuring on the mirror.

Measured WFE map after ion figuring

REOSC SAGEM

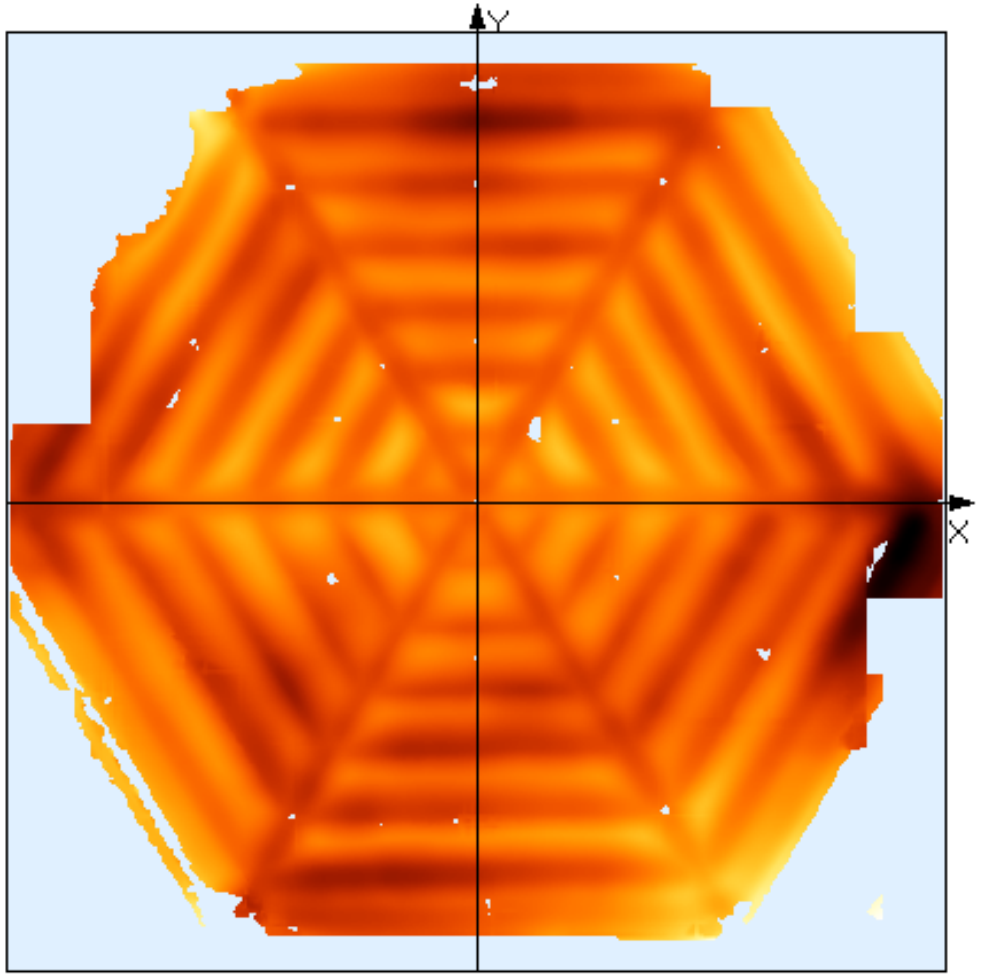
WaRPP v 3.01 PRO

Usion 3

Date : 24/04/02

Heure : 15:45:54

```
Surface
L = 632.80 nm
R = 0.000 mm
Résol. : 350x350
Echelle Lin. :
  -7963.842 nm à
  10371.839 nm
91289 points
Min = -7963.842 nm
Max = 10371.839 nm
Moy = -23.372 nm
P-V = 18335.680 nm
RMS = 2001.720 nm
```



X = -0.5971 Y = 0.1744 R = 0.6220 Z = 1470.1990 nm

Conclusions

The WFE obtained after ion figuring are close to the expected values:

PTV = 18,3 µm to be compared to PTV=18,7 µm
RMS = 2 µm to be compared to RMS = 2, 13 µm

No evolution in the surface micro roughness has been evidenced.

Summary

- Hybrid Technology on Track
- Successful Cryogenic and Structural Demonstrations
  - MinimumTemperature Exposure of 25K;
  - Nominal Test Temperature 40K
  - Figure Repeatability (No Apparent Hysterisis)
  - Agreement Between Test and Analytical Predictions
    - Quilting Analysis Model Updated Based on 2nd Cryo Test
    - Predicted Modal Behavior Consistent with Measurements
- Cryo-Figuring Complete
- Final Cryo Test Awaiting Facility Availability